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Dewatering of Coal-Clay Waste Slurries From Preparation Plants

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UNITED STATES DEPARTMENT OF THE INTERIOR

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James G. Watt, Secretary

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CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	min	minute
gal	gallon	pct	percent (by weight)
gal/min	gallon per minute	pH	negative log of the hydrogen ion concentration
in	inch	r/min	revolution per minute
lb	pound		
lb/ton	pound per ton		

DEWATERING OF COAL-CLAY WASTE SLURRIES FROM PREPARATION PLANTS

By P. M. Brown[1] and B. J. Scheiner[2]

ABSTRACT

The Bureau of Mines is investigating a dewatering technique for coal-clay waste that uses a flocculant, polyethylene oxide (PEO). This flocculant forms strong stable flocs that can be dewatered on a static screen. A field test unit (FTU) using this technique was operated at approximately 400 gal/min, using a waste stream from the flotation circuit of a coal preparation plant. Consolidated coal-clay material containing 55 to 60 pct solids was produced when the flotation circuit slurries of 2.7 to 8 pct solids were treated with 0.1 to 0.3 lb PEO per ton of solids. The FTU was also operated at 64.5 and 87.5 gal/min using a portion of the underflow slurry from the preparation plant's thickener. Consolidated coal-clay material containing 55 to 60 pct solids was produced when the thickener underflow slurries of 19 to 24 pct solids were treated with 0.08 to 0.2 lb PEO per ton of solids. PEO-treated materials continued to dewater when placed in a pit.

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INTRODUCTION

A slurry waste product containing fine coal and clay is generated in the processing of coal to a low-ash material. This waste product is difficult to handle because of the slow settling of the fine-sized particles—generally less than 28 mesh in size, with the majority less than 325 mesh. The material is usually treated with a flocculant and sent to a thickener to produce a slurry containing 20 to 30 pct solids. This thickened slurry is then impounded behind earthen dams. It has been estimated that approximately 16 million tons of waste contained in slurries are generated annually (1).[3] Disposition of the slurries behind dams poses a potential health and safety hazard because of possible dam failure (2-4) and because months and sometimes years are required for the slurry to settle and thicken naturally.

The Bureau of Mines, as part of its mission to eliminate health and safety hazards at the mine site, is investigating alternate treatment and disposal methods for coal mine waste (2-8). One technique consists of mixing the slurry with a flocculant, such as PEO, and dewatering the resultant flocs on static hydrosieve screens. Previous Bureau research has shown that industrial wastes such as phosphate slime, potash-clay waste, uranium mill tailings, and talc tailings can be dewatered successfully and consolidated to become stable products (6-7). The present report describes field test research efforts to dewater coal-clay waste slurries from a commercial preparation plant located at Brookwood, AL, using the Bureau's technique to eliminate the need for ponding of the slurries behind earthen dams.

ACKNOWLEDGMENT

This research was conducted under a memorandum of agreement between the Bureau of Mines, U.S. Department of the Interior, and Jim Walter Resources Inc., owner of Jim Walter No. 7 Mine, located in the vicinity of Brookwood, AL. The authors wish to express their appreciation to Jim Walter personnel for assisting in the FTU operation.

MATERIALS, EQUIPMENT, AND PROCEDURES

Two coal-clay waste slurries were obtained from the preparation plant at Jim Walter Resources' No. 7 Mine. One slurry was the minus 28-mesh coal tailings from the flotation circuit, and the other slurry was the thickener underflow. The flotation circuit slurry contained 2.7 to 8.1 pct solids, and the thickener underflow contained 18.5 to 24.1 pct solids. Particle size distribution of the two slurries, given in table 1, shows that the majority of the material was less than 325 mesh in size; the flotation circuit contained 60.1 pct minus 325 mesh, and the thickener underflow contained 43.6 pct minus 325-mesh particles. X-ray diffraction analyses conducted on the minus 325-mesh fraction indicated that it contained amorphous material, presumably coal, together with kaolinite, mica, quartz, minor amounts of chlorite, microcline, and a mixed layer material of mica and montmorillonite. Microscopic examination of the plus 325-mesh fractions identified coal, coarse crystalline quartz and mica, and a considerable amount of microcrystalline material presumed to be shale.

TABLE 1. - Screen analysis of coal-clay waste slurries, percent

Screen size, mesh	Flotation circuit	Thickener
Plus 28	4.6	13.2
Minus 28 plus 48...	7.4	15.0
Minus 48 plus 100..	8.7	13.3
Minus 100 plus 150.	5.8	5.6
Minus 150 plus 200.	5.9	4.6
Minus 200 plus 270.	4.1	2.6
Minus 270 plus 325.	3.4	2.1
Minus 325..........	60.1	43.6
Composite total.	100.0	100.0

[3]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

The flocculant used in all dewatering tests was PEO, a commercially available polymer having a nominal molecular weight of 8 million. PEO is a linear, nonionic, water-soluble molecule composed of repeating units of CH_2-CH_2-O. A stock solution of 0.25-pct PEO was prepared using water from the preparation plant. More dilute solutions of PEO were prepared by dilution of the stock solution with preparation plant water.

The flowsheet for large-scale tests is shown in figure 1. The FTU was installed at Jim Walter Resources' No. 7 Mine. Coal-clay slurry was supplied to the FTU from either the flotation circuit of the preparation plant or from the thickener underflow. The slurry flowed to a holding tank where its pH was adjusted from initial pH values of 7.5 to 8.5 to a desired value with lime or caustic soda. It was then pumped to a mix tank where PEO was added, and the resulting flocculated material was passed over a set of static screens (hydrosieve) for removal of water. The hydrosieve was 8 ft wide and 8 ft long and was built in two sections of stainless steel wedge-wire screen that permit independent angles of inclination for each section. The upper section of the screen (8 ft wide, 4 ft long) has slot openings 2.75 in long and 0.02 in wide. The lower section of screen has slot openings 2.75 in long and 0.01 in wide. A view of the FTU is shown in figure 2. Dewatered material from the hydrosieve is conveyed to a pit, where further dewatering occurs, as shown in figure 3.

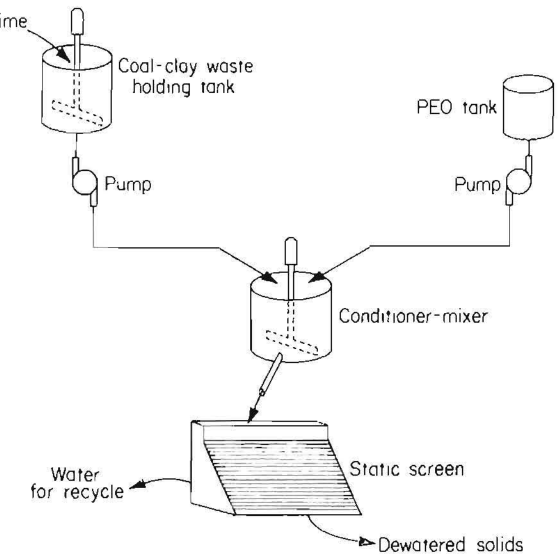

FIGURE 1. - Field test flowsheet.

RESULTS AND DISCUSSION

Based on the laboratory- and small-scale testing (8), it was evident that a system for the continuous treatment of coal-clay waste slurries has three basic requirements for a successful operation. (1) The coal-clay waste feed must be at the proper pH range prior to PEO treatment. (2) There must be proper mixing of the coal-clay slurry with the PEO reagent. (3) The movement of the flocculated material over the static screens must be in such a manner to produce rapid removal of water with minimum breakdown of flocs. The FTU was operated to determine the optimum conditions for continuous dewatering of coal-clay waste slurries.

FLOTATION CIRCUIT SLURRY

The first coal-clay waste stream tested was from the flotation circuit of the preparation plant. A 400-gal/min fraction of the flotation circuit's waste stream was sent to the FTU for dewatering. Preliminary experiments indicated that a pH of 9 or higher was required to obtain strong flocs. Also, 5 min of reaction time was required after lime addition prior to flocculation with PEO. This was accomplished in two 1,000-gal tanks connected in series. Typical lime requirement was approximately 1.5 lb/ton.

Control of the variables of the PEO-slurry mixing chamber, such as position, radius, and revolutions per minute of the stirrer blade, proved very critical in obtaining a dewatered product that was high in solids content and an underflow water that was low in solids. Table 2 lists the variables tested, the amount of PEO used, and the percent solids found in the dewatered product and in the

TABLE 2. - Effect of stirrer length, location, and speed on dewatering efficiency[1]

Position of stirrer, in from bottom of mixer	Stirrer, r/min	pH	PEO, lb/ton	Solids discharged, pct	Solids in underflow water, pct
STIRRER RADIUS, 6.5 in					
9..........	28	8.94	0.19	53.2	0.64
	40	9.35	.18	56.9	.92
	58	9.27	.22	55.6	.73
5..........	28	9.53	.22	56.9	.44
	40	9.48	.25	52.4	.62
	58	9.74	.25	52.8	.68
1..........	28	9.43	.25	56.6	.85
	40	9.41	.15	52.8	1.60
	60	9.00	.24	45.0	.74
STIRRER RADIUS, 10.5 in					
9..........	28	9.40	0.26	60.2	0.76
	40	9.37	.32	60.6	.70
	60	9.45	.29	57.9	.73
5..........	28	9.43	.23	58.9	.63
	40	9.10	.14	57.7	1.15
	60	9.41	.29	59.2	.59
1..........	28	9.20	.24	58.9	.87
	40	9.24	.25	58.2	.67
	60	9.20	.26	57.4	.33
STIRRER RADIUS, 15.5 in					
9..........	28	9.42	0.18	56.0	1.08
	40	9.26	.20	51.8	.63
	60	9.50	.22	53.3	1.67
5..........	28	9.33	.20	55.2	.71
	40	9.46	.16	55.6	.68
	60	9.43	.20	57.2	.60
1..........	28	9.38	.23	56.7	.42
	40	9.44	.15	53.2	.35
	60	9.20	.23	53.2	.44

[1]Unit operated at 400-gal/min feed rate, and 0.025-pct PEO was used for these experiments.

hydrosieve underflow water. In every case, the solids in the underflow water settled rapidly, producing a water that could be readily discharged or recycled for plant use. Based on PEO dosage, dewatered solids, and underflow solids, it was found that the PEO-slurry mixing chamber performed best with a stirrer of 15.5-in radius positioned 1 in from the bottom of the mixer and rotating at 28 r/min.

The angle of inclination of the hydrosieve screens, as shown in table 3, influenced the solids content of the dewatered product and the percent solids in the underflow water. An angle of 50° for the lower screen and 58° for the upper

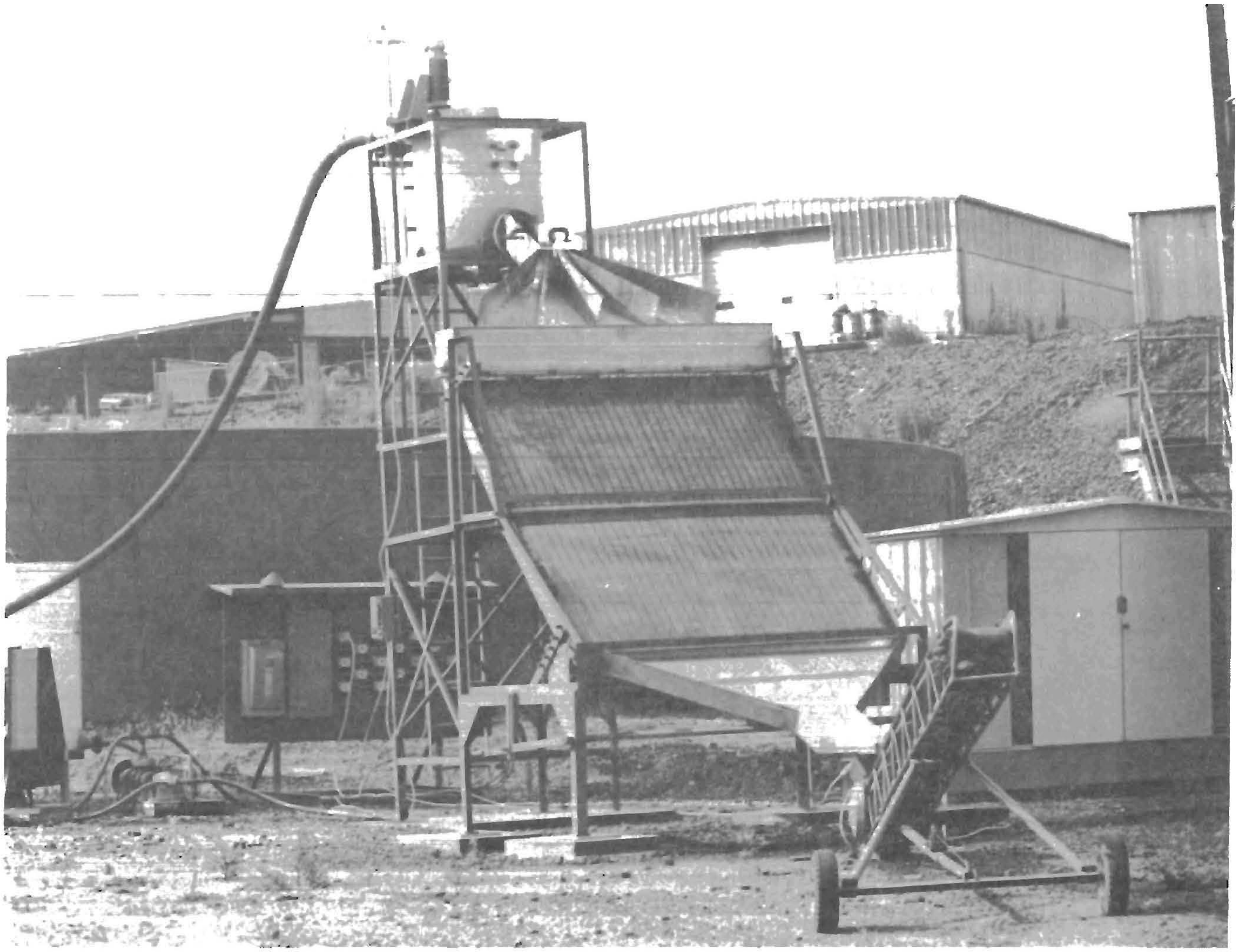

FIGURE 2. - View of FTU at Jim Walter Resources' No. 7 Mine located in Brookwood, AL.

TABLE 3. - Effect of angle of hydrosieve screens on dewatering efficiency[1]

Lower screen	PEO dosage, lb/ton	Solids discharged, pct	Solids in underflow water, pct
UPPER SCREEN, 58°			
50°	0.22	63.2	0.66
45°	.22	61.2	1.53
38°	.24	56.5	.85
35°	.44	54.7	.93
UPPER SCREEN, 55°			
50°	0.54	54.6	3.42
45°	.51	50.8	2.47
38°	.49	59.0	.77
35°	.43	54.6	1.75

[1]Unit operated at 400-gal/min feed rate, and 0.025-pct PEO was used for these experiments; 3 pct feed solids.

screen produced 63 pct solids in the dewatered product and 0.66 pct solids in the underflow water, using 0.22 lb PEO per ton solids. The higher angles of inclination made the flocculated material roll down the screen instead of sliding down. Material that slid was grated by the screens, thereby producing solids in the underflow water, whereas the process of rolling served to compact the flocs and to liberate water.

Optimum operating conditions positioned the 15.5-in-radius stirrer blade 1 in from the bottom of the mixer, the upper screen angle at 58°, and the bottom screen angle at 50°. With these optimum conditions, waste slurry from the flotation circuit was dewatered from a 3 pct

FIGURE 3. - FTU in operation, with dewatered material being discharged to a pit where further dewatering occurs.

feed slurry to 63 pct solids with 0.7 pct solids in the underflow water. These results were obtained repeatedly over several days of operation. Reagent consumption was 0.22 lb PEO per ton of solids and 1.5 lb lime per ton of solids.

THICKENER UNDERFLOW SLURRY

Attention was then turned to the coal-clay slurry from the processing plant's thickener underflow to determine how well the dewatering method would dewater slurries with high solids content. Small-scale tests had indicated that slurries with high solids content should dewater with little or no modification needed on the FTU (8).

Initial tests indicated that the pH of the thickener underflow slurry had to be raised to a minimum value of 8.8. The effect of pH in the 8.8 to 9.5 range is shown in table 4. In all subsequent tests the pH was maintained at 9.0 or higher. Also, the reaction time required for the lime to condition the slurry prior to PEO addition was 6 min.

TABLE 4. - Effect of pH on solids content of dewatered product from thickener (0.10 pct PEO; PEO dosage 0.09 lb/ton; 22.6 pct solids; lime dosage 0.1 lb/ton)

pH[1]	Solids discharged, pct	Solids in underflow water, pct
8.8	53.7	1.8
9.1	58.5	2.2
9.5	57.3	1.4

[1]Of slurry and of underflow water.

In previous tests, the underflow solids from the screen had been greater than 1.0 pct. A series of tests was conducted to determine the effect of PEO dosage on underflow solids, as shown in table 5. The results indicated that as the PEO dosage increased, the amount of solids in the underflow water decreased. An increase in PEO concentration meant more PEO available to bond with the particles. This additional bonding produced flocs that were more able to withstand shear on the hydrosieve screens. An increase in PEO had no effect on the percent solids in the dewatered product until enough PEO was in the system to clog some of the screen's slits. At 0.82 lb/ton PEO, the hydrosieve screen became clogged. This condition resulted in a decrease of percent solids in the dewatered product.

TABLE 5. - Effect of PEO dosage on solids content of dewatered product from thickener underflow (0.10 pct PEO; 21 pct solids; pH 9.4)

PEO dosage, lb/ton	Solids discharged, pct	Solids in underflow water, pct
0.08	54.1	2.2
.09	57.8	1.4
.10	53.2	1.2
.19	53.0	1.3
.38	50.5	.96
.45	51.0	.85
.82	[1]42.3	.82
1.40	[1]41.8	.57

[1]Excess PEO caused some of the screen slits to be clogged.

The stirring rate of the PEO-slurry mixing chamber was also studied (table 6). The optimum size of the stirring blade (15-in radius) and its position in the chamber (1 in from bottom) were found to be the same as that used for the flotation circuit slurry. The optimum stirring rate was found to be 30 r/min. This produced a dewatered product with 58 pct solids, using 0.13 lb PEO per ton solids.

TABLE 6. - Effect of conditioner stirring rate on solids content of dewatered thickener (0.10 pct PEO; PEO dosage 0.13 lb/ton; 20.2 pct solids; 6.0 pct lime; lime dosage 0.21 lb/ton; pH 9.5)

Stirring rate, r/min	Solids discharged, pct	Solids in underflow water, pct
20	51.8	2.3
30	58.3	1.4
40	55.3	2.0
50	57.3	1.9
60	50.5	3.7
70	56.7	6.5

Using optimum conditions, the thickener underflow slurry feeding at a rate of 64.5 gal/min produced a solids containing 57.8 pct solids and 1.4 pct solids in the underflow water. The reagent consumption was 0.09 lb PEO per ton and 0.1 lb lime per ton.

The flow rate of the thickener underflow slurry was increased to 87.5 gal/min, and the slurry was dewatered. A 20.5 pct feed slurry produced 58.3 pct solids in the dewatered product and 1.3 pct solids in the underflow water, using 0.12 lb PEO per ton and 2.1 lb lime per ton.

These experiments show that the FTU can readily dewater coal-clay waste slurry either from the coal preparation plant's flotation circuit or from its thickener.

Research is now in progress to determine the stability of dewatered material when mixed with coarse refuse from the preparation plant. Dewatered material has been mixed with coarse refuse in a ratio of 1 to 5 to form a stable material that can be stacked. These mixtures are now being monitored to determine their long-term stability.

SUMMARY AND CONCLUSIONS

Coal-clay waste slurries from the flotation circuit and from the thickener underflow of a coal preparation plant were successfully dewatered using PEO as a flocculant. The feed from the flotation circuit was treated at flow rates as high as 400 gal/min, with 2.7 to 8 pct solids content. The feed from the thickener underflow had flow rates of 64.5 and 87.5 gal/min, with 19 to 24 pct solids content. Coal-clay waste slurries from each feed source were dewatered to 55 to 60 pct solids content using 0.08 to 0.3 lb PEO per ton of coal-clay waste.

Field testing of the coal-clay waste dewatering process will continue to obtain the engineering data needed to scale up this equipment to handle the entire waste stream of a coal preparation plant.

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